Metallic Environmentally Resistant Coating Rapid Innovation Initiative (MERCRII)

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Introduction

Mission concepts such as JPL's Endurance-A utilize rovers such as Astrolab's FLEX concept to explore the lunar surface. For these types of systems, lightweight alloys such as aluminum (Al) and titanium (Ti) are often specified to minimize mass while maintaining structural integrity. Such alloys, however, exhibit poor tribological response in the form of high friction and wear, especially in extreme space environments and with the additional presence of lunar regolith. This shortens the lifetimes of these systems which have a requirement to traverse 1,00km/year. This project is addressing the technology need of this and future rover missions by developing advanced wear- and radiation-resistant coatings for lightweight parts to extend the lifetime and sustainability of both lunar and Martian assets.

Objectives

- Develop coating configurations to reduce wear on the conventionally manufactured (CM) and additively manufactured (AM) parts
- Determine appropriate criteria to assess regolith simulant abrasion on samples exposed to simulated lunar environments, including temperature extremes and radiation
- Characterize Al and Ti substrates' tribological performance and how coatings improve performance
- Demonstrate coating performance on multiple mechanism joint types
- Contribute to future lunar dust mitigation investigations, providing real data of mechanical behavior for future lunar hardware

Pathfinder

Pathfinding tests and trials were run to determine several testing and coating parameters for main testing phases:

- Wear Testing:
  - Test type: Pin-on-Disk
  - Load: 9N
  - Speed: 50rpm
  - Duration: 1800s
- Simulant choice: JSC-1A
- Coating Materials
- Coating Application: (different for each coating)
  - Application methods
  - Particle speed
  - Standoff distance
  - Temperature
  - Bonding layers

Pin-on-Disk Test During Pathfinder Trials

Coatings & Application Methods

Coatings

1. Aluminum Oxide (Al_2O_3)
2. Ti64 with 2vol%BN (Ti-2%BN)
3. Ti64 with 10vol%BN (Ti-10%BN)
4. Nickle Titanium-Hafnium (60NiTi-Hf) with Tungsten Disulfide (WS_2) film

Working with 2 external partners for coating applications*

*Applied Tungstenite applied WS_2 film

Application Methods

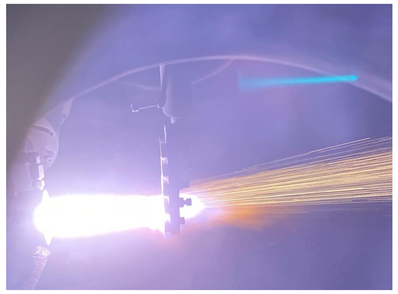
1. High Pressure Cold Spray (CS)
2. Vacuum Plasma Spray (VPS)
3. Ambient Plasma Spray (APS)

Each combination of material and application method makes a single configuration

MERCRII
Metallic Environmentally Resistant Coating Rapid Innovation Initiative

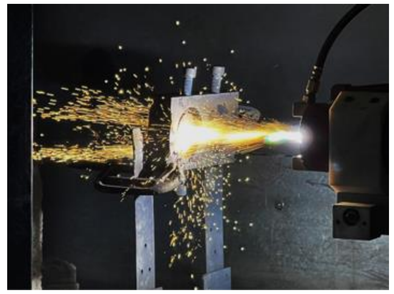
Plasma Process

High Pressure Cold Spray



Vacuum Plasma Spray

Florida International University



Ambient Plasma Spray

Phase I

Coatings Applied to CM Substrates, exposed to lunar simulating environments, and wear tested in ambient conditions

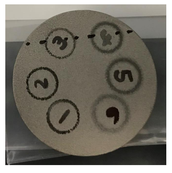
Environmental Exposures

- Radiation
  - Electron Energy: 400 keV
  - Electron Flux: 1 nA/cm^2
  - Flat Dose: 6 Mrad
- Thermal Vacuum Cycling
  - Profile Range: –175 ± 10 °C to 120 ± 10°C
  - Cycle Duration: 6 hours
  - Cycle Count: 60 cycles (~2.3 simulated lunar years)

Testing

- Pin-on-Disk Wear Tests
  - At ambient conditions
  - 6 Tests per exposure type:
    - 3 tests w/o regolith simulant
    - 3 tests w/ regolith simulant

Pelletron Beam Line



Ti-10%BN VPS Sample Post Wear Testing (cross sectioning line shown)

Pin-on-Disk Testing w/ Regolith

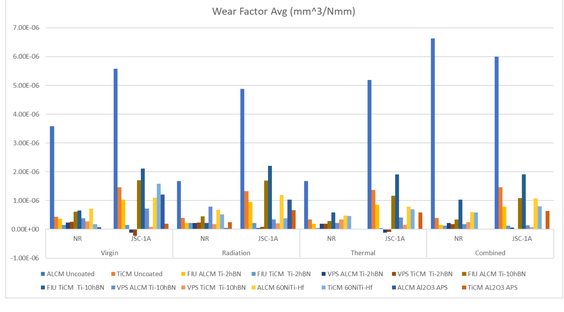
V3 Thermal Vacuum Chamber

Phase I Results

- 7 Configurations tested (see table to right), down-selected to 3 configurations for Phase II testing
- 3 Highest Performing Configurations:
  - Ti-2%BN VPS showed the best wear test performance
  - Ti-2%BN APS showed good wear test performance
  - Ti-10%BN VPS showed good wear test performance
- Further analysis being conducted (data not yet compiled)
  - Surface and cross section SEM
  - Surface XRD
  - Hardness and microhardness
  - Radiation shielding

Wear Factor (Mass Removed) Comparison Graph

Averaging the 3 Tests w/o (NR) and w/ (JSC-1A) Regolith for each Configuration



Phase II

Coatings applied additionally to AM substrates. Phase I testing repeated for AM and additional testing performed for both substrate types

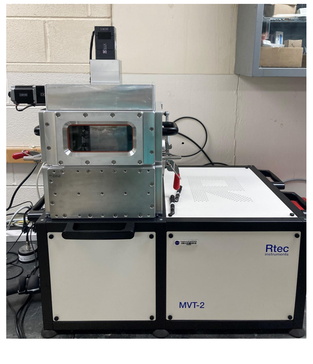
Environmental Exposures

- Repeat exposures of Phase I

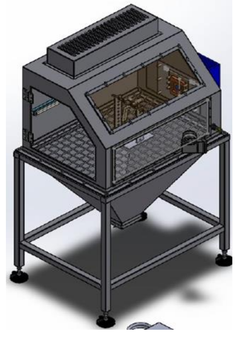
Testing

- Pin-on-Disk Wear Tests
  - At vacuum
  - 6 Tests per exposure type:
    - 3 tests w/o regolith simulant
    - 3 tests w/ regolith simulant
- Surface Erosion Tests
  - High velocity regolith impact
  - At cryogenic temperatures

Vacuum Tribometer



Erosion tester developed at FIU



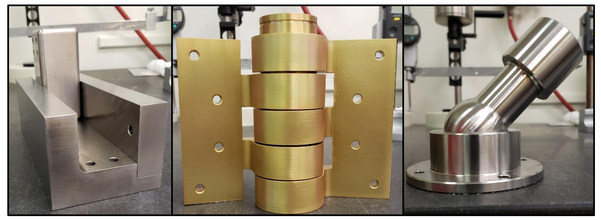
MISSE-17

- 6 samples flying to the ISS on the MISSE-17 mission
- Exposure to radiation, atomic oxygen, thermal cycling, high vacuum

Coating	AlCM Substrate	TiCM Substrate
Uncoated	1	–
Ti-2vol%BN APS	1 coated both sides	1 coated both sides
Ti-2vol%BN VPS	1 coated both sides	1 half coated both sides
60NiTi-Hf	1 coated both sides	–

Phase III Planned Testing

- Single coating selected: Ti-2%BN VPS
- Applying coatings to CM and AM mechanisms
- 3 mechanisms of action:



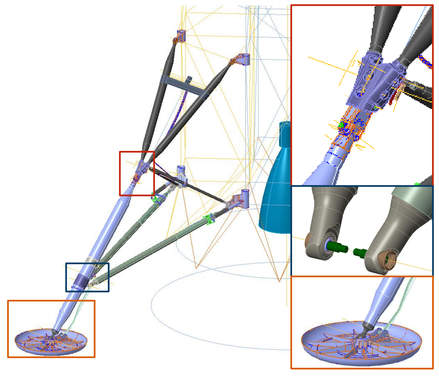
Rod and Slot **Hinge Joint** **Ball and Socket**

Test Parameters

- Initial 100 lbf preload
- Baselining 500-750 cycles
- Operating 200°F at 10 Torr
- Depositing regolith simulant

Mechanism Test Chamber

Mechanisms are designed to replicate the rolling and torsion motion from lander concepts provided by LaRC and from Apollo missions



Acknowledgements

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